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MOSQUITO BURDEN AND IMPACT ON THE POOR: MEASURES AND COSTS FOR PERSONAL PROTECTION IN SOME COMMUNITIES IN THAILAND

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ABSTRACT. To gauge the extent of mosquito problems and their impact on local people in Thailand, a simple questionnaire was designed consisting of 6 questions with multiple choices to be answered in 4 different communities in Thailand in 1998 and 1999. Mosquito biting activity was noted often by respondents. They reported that mosquitoes bit both night and day, and that the insects were abundant both in the dry and the rainy seasons. In all 4 communities, a large proportion of the residents used bed nets, mosquito coils, and aerosol sprays for personal protection; vaporizing mats and repellents were used sparingly. The cost of such measures amounted to $4 to $25 per year per household. For most of the residents, this represented a substantial proportion of their income, and was proportionally greater than the average cost of organized mosquito control in developed countries. This suggests that instituting organized local vector control programs would be cheaper and more effective than the individual use of personal protectants that do not reduce mosquito numbers. An assessment of the available products stocked in neighborhood stores and supermarkets for personal protection was made. A variety of insecticidal aerosols, mosquito coils, liquid sprays, vaporizing mats, and vaporizing liquids was stocked. This ample supply of household insecticides lends support to the preferred methods of protection reported by the respondents. The active ingredients in most of the formulations were synthetic pyrethroids, although a few contained dichlorvos, propoxur, and a few other compounds. Mosquito coils, the most preferred products used by the poor, were evaluated for efficacy, and were found to provide a reduction of 72–96% in landing–biting rates in controlled experiments.

KEY WORDS Mosquitoes, personal protection, aerosols, insecticidal coils, costs of mosquito control, Thailand

INTRODUCTION

In the course of studies on the control of mosquito larvae in small communities in Nonthaburi Province of Thailand (Mulla et al. 1997, 1999), we found that all squatter communities (especially Soi Jumpa, Soi Raevadee, and Wat Pikul) harbored extremely heavy densities of mosquito larvae (primarily *Culex quinquefasciatus* Say) in standing water under and around the raised dwellings, as well as in polluted water canals (klongs) draining these water accumulations. Additionally, these communities were infested with *Aedes aegypti* (L.) breeding in water storage jars and tanks in and around the houses. As a result of heavy larval populations of *Cx. quinquefasciatus,* adults of this species were extremely abundant in and around the dwellings. Residents were attacked by hundreds of host-seeking *Cx. quinquefasciatus* at night, and black light traps placed 1 night a week inside or outside houses for about 8 months in 1999 and 2000 collected up to 3,000 or more *Cx. quinquefasciatus* per trap per night. Although larval treatments with microbial insecticides seemed to ameliorate the problem, the currently administered provincial mosquito control program for adult mosquitoes, consisting of monthly thermal fogging, did not seem to help.

In the communities where we conducted our studies monthly incomes were equivalent to $100–$300 per household. To gain relief from mosquitoes, the residents purchased and used a number of insecticidal products for personal protection. Because of the severe mosquito problem, we prepared a simple questionnaire to gain information on public perception of mosquito annoyance and the costs involved in purchase of chemicals and devices for personal protection.

MATERIALS AND METHODS

Questionnaire

The questionnaire was designed to seek information on the impact of adult mosquitoes on the local people and to gauge the spectrum of protective measures employed. The questionnaire was written in the Thai language. The approach used with these questionnaires was different from that used by Morris and Clanton in Florida (1988, 1989). We sought to determine the type of measures available and routinely employed by the residents for personal protection. In addition to the questionnaire, we surveyed household insecticidal products labeled for personal protection from mosquitoes and stocked in small neighborhood stores as well as large modern supermarkets in several areas of Thailand.

Members of the households were personally interviewed by the entomology staff of the Department of Medical Sciences, National Institute of Health, Ministry of Public Health, in Nonthaburi. The surveyors either visited the residences or se-

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cured the information from storeowners or vendors. All information collected was through personal contact. The surveys were carried out in 4 different areas of Thailand, including 2 in Nonthaburi Province (central), 1 in Chiangmai Province (northern), and 1 in Suratthani Province (southern).

Questionnaires gained information on the number of residents (related or unrelated) per household, biting frequency and intensity of mosquitoes, mosquito host-biting diel cycles, and mosquito abundance and activity by seasons (dry and rainy). One question addressed measures used for personal protection such as bed nets, mosquito smoke coils, aerosols and sprays, and repellents. Another question was designed to gain information on the annual costs for residents for purchase of insecticidal products from local stores and markets. The questions did not include purchases of insecticides for other household insects.

Insecticidal products for personal protection

In order to determine the kinds of antimosquito products available for sale to the public, small neighborhood stores (results not reported) as well as small convenience stores (results not reported) and modern supermarkets were surveyed. Product surveys were carried out in 5 small or midrange neighborhood stores located in rural or semiurban areas. Additionally, 3 large modern supermarkets (results for 1 market reported) were visited in urban areas. The product surveys covered the central part of Thailand (Bangkok and Nonthaburi provinces) and 2 provinces in northern Thailand (Chiangmai and Mae Hong Son). The products available at the time of survey were categorized into aerosols, mosquito coils, liquid sprays, and vaporizers.

Efficacy of mosquito coils

Because mosquito coils are the preferred antimosquito products used by low-income communities, we evaluated 3 representative commercial products from among those available to the public. These coils were Baygon (0.03% transfluthrin; Bayer Thai Co., Bangkok, Thailand), Swan 2 (0.2% D-allethrin; Swan Co., Ltd., Thailand), and Elephant 2 (0.15% esbiothrin; Fumakilla/Technopia, Penang, Malaysia). The coils were tested outdoors in Soi Jumpa, Pak-Kret District, Nonthaburi Province for 1 night each in September, October, and November of 1999. The test procedure consisted of capture of landing and biting mosquitoes on legs (bared from knee to ankle) of 4 volunteers. One individual served as a control and was not positioned close to a mosquito coil. The other 3 were seated 5 m away from one another and close (0.5 m) to 1 of 3 burning coils. A total of 12 collections were made, each collection for a 10-min duration each night from 1800 to 2100 h. The volunteers, including the control, were rotated clockwise after each collection

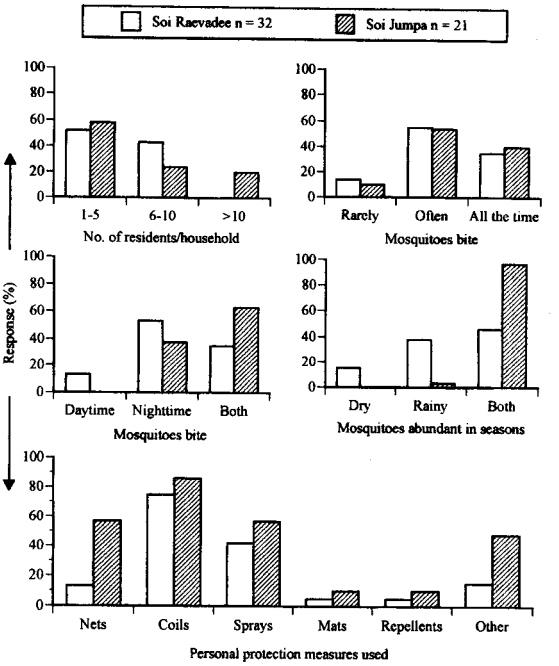

Fig. 1. Mosquito abundance and annoyance levels, and protective measures used by residents in 2 low-income communities in Pak-Kret District, Nonthaburi Province, in central Thailand based on responses to questionnaires in 1998 and 1999.

time (10 min) and the individual coils were also rotated after every 4th collection. This experiment was designed to equalize positional effects and individual factors of attraction to mosquitoes.

The captured mosquitoes were brought into the laboratory, counted, and segregated into species. Percent protection from mosquito landing and biting was calculated for each treatment as compared to controls.

RESULTS AND DISCUSSION

Mosquito abundance, impact, and protective measures

The questionnaire was presented orally to either the head or members of households and the responses to each question or statement were recorded. The same questions were presented to each respondent in the same order. Residents of different communities gave similar responses to the questions.

The residents in the 2 adjacent communities (Soi Raevadee and Soi Jumpa, Nonthaburi Province) in central Thailand provided similar responses with regard to mosquito annoyance and the use of measures for personal protection (Fig. 1). In these communities, the number of residents per household was high, ranging from 4 to 12 individuals per dwelling. These communities had extremely high

numbers of mosquitoes. The majority of residents stated that mosquitoes bit often or continuously. They also reported that mosquitoes bit both day and night, a clear indication of the presence of *Ae. aegypti* and *Cx. quinquefasciatus*. The seasonal abundance of mosquitoes in these communities was perceived to be essentially the same in both rainy and dry seasons.

We trapped *Cx. quinquefasciatus* mosquitoes at night in 1999 and 2000 by placing black light traps inside or outside the dwellings. It was not uncommon to trap up to 3,000 or more male and female *Cx. quinquefasciatus* per night-trap, with no capture of *Ae. aegypti*, a species not attracted to this type of trap.

Another important aspect of the impact of mosquitoes and their importance as annoying pests to the residents was the widespread use of personal protection measures. Bed nets, aerosol preparations, sprayable liquid formulations, and mosquito coils were the most preferred measures used by the residents (Fig. 1). Vaporizing mats (too expensive for low-income residents) and repellents (the types and quantities stocked in stores were limited) were used sparingly. Other measures, such as fans, screened windows, and skin oils, were used by some of the residents. A higher proportion of the residents in Soi Jumpa used bed nets than in Soi Raevadee; the former community is somewhat better off economically but had higher numbers of mosquitoes.

The same questionnaire and procedures were used in assessing the importance and impact of the biting and nuisance level of mosquitoes in 2 distantly located communities in northern and southern Thailand (Fig. 2). In the Mae Tang District (Chiangmai Province in the north) the proportion of households with 1–5 individuals per household was greater than that in Chaiya District (Suratthani Province in the south) but the latter indicated more families with 6–10 individuals per household than the former. In both communities, the response to mosquito bites was similar. A majority of the respondents in both communities also reported that mosquitoes bit often and during both night and day. In these communities, mosquitoes were perceived to be more abundant in the rainy season. This may reflect the greater breeding of *Aedes albopictus* (Skuse) in rural areas during the rainy season. This is in contrast to the situation in Soi Raevadee and Soi Jumpa in central Thailand, where mosquito developmental sites are permanent and created by domestic wastewater, including sewage seepage into the canals and other standing water accumulations. These conditions are conducive to heavy production of *Cx. quinquefasciatus*. The rural areas in Mai Tang and Sura Thani are relatively free of organic pollution and therefore have lighter infestations of *Cx. quinquefasciatus*.

The products and measures used for personal protection were essentially the same in the Mae Tang and Chaiya districts (Fig. 2) and similar to the use patterns in central Thailand. Bed nets, mosquito coils, and sprays (mostly aerosols) were the most preferred tools for personal protection.

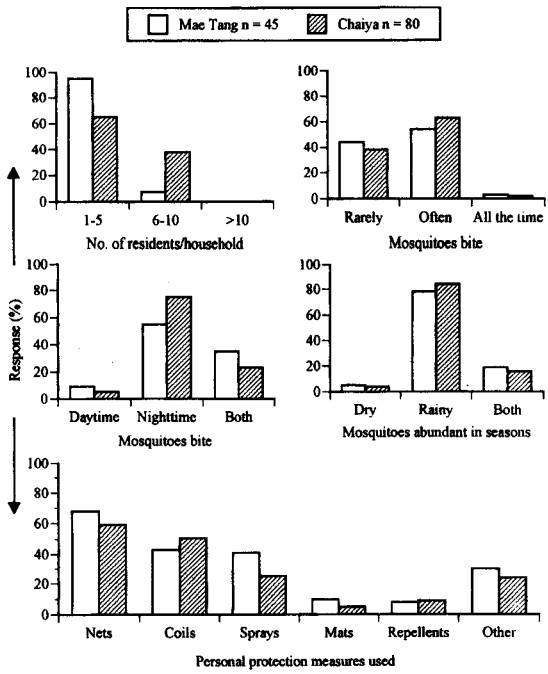

Fig. 2. Mosquito abundance and annoyance levels, and protective measures used by residents in 2 low- to moderate-income communities in Mae Tang District (Chiangmai Province) and Chaiya District (Suratthani Province) in northern and southern Thailand, respectively, based on responses to questionnaires in 1999.

Cost of personal protection

The questionnaire provided information on the costs to residents for products used for personal protection against mosquitoes. In Soi Raevadee and Soi Jumpa communities, with heavy populations of mosquitoes, the cost for most of the residents was very high (B500 to >B1,000 per residence per year [$12.50 to >$25]; Fig. 3). In the Mae Tang and Chaiya areas, costs were somewhat lower (B100–B1,000 [$2.50–$25]). These expenditures for mosquito protective measures are much higher than the average costs of organized mosquito control on a per residence basis in industrialized nations. For example, in southern California, where most of the counties are protected by organized mosquito and vector control district programs, the cost of comprehensive vector control is much cheaper per parcel or household than for poor sectors in Thailand. The cost per parcel averages about $2.25 in the Northwest Mosquito and Vector Control District in Riverside County of southern California (Major S. Dhillon, personal communication). In Orange County, the annual cost per parcel is about $5.00

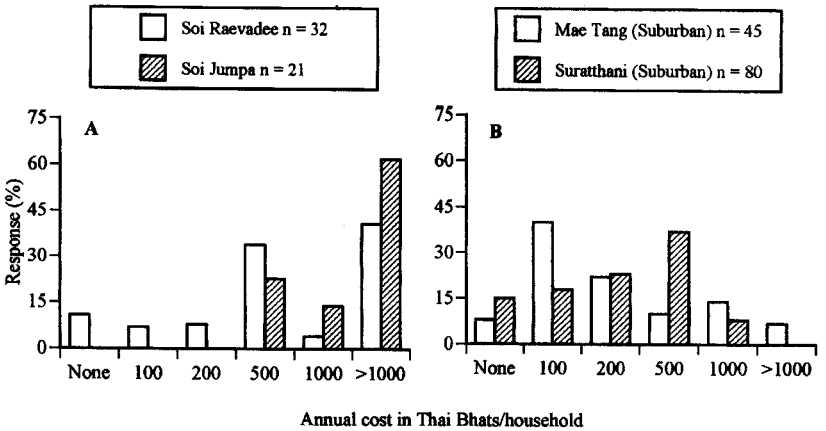

Fig. 3. Annual cost for personal protection from mosquitoes based on responses to questionnaires in 1998 and 1999 by residents of Soi Raevadee and Soi Jumpa (A) and Mae Tang District and Suratthani Province (B).

per year (Robert D. Sjogren, personal communication). The Greater Los Angeles County Vector Control District reported an average cost per parcel of $4.07 per year (Jack Hazelrigg, personal communication).

The cost of organized mosquito control in the Rhine River Valley is about DM2 (= $1.20) per person per annum (Norbert Becker, personal communication). The difference in costs for vector control programs in developed regions vis-à-vis poor communities in Thailand is likely true for most developing countries in the tropics. We conclude that the cost of instituting organized local vector control programs in Thailand would be lower than the aggregate costs borne by individuals, households and provincial programs in mosquito-infested communities.

Insecticidal products for personal protection

We prepared a list of the most commonly used aerosols, sprays, mosquito coils, and vaporizing products available with their chemical composition (active ingredients only). Table 1 lists the aerosol formulations available in Thailand for personal protection against mosquitoes. Six companies were the providers of these products. Most of the formulations we found contained 1 or more synthetic pyrethroids. Dichlorvos, an organophosphate, was the next most frequently encountered chemical in formulations, followed by propoxur, a carbamate insecticide. One formulation contained fenitrothion along with 2 other insecticides.

A similar survey was made for the most commonly available mosquito coils and vaporizers (Table 2). Ten companies were involved in the manufacturing and distribution of coils. The formulations used in vaporizers (electric heating units) were either liquid or solid, and each type was dispensed with specially made electric vaporizers. The active ingredients in the mosquito coils and in the vaporizing units were solely synthetic pyrethroids.

In terms of ease of application, sustained release over night, and cost, the mosquito coils are the cheapest products available on the market. Most of the residents we talked to reported constant use of mosquito coils. The vaporizers were not used commonly by low-income communities because of the high cost of insecticides as well as the electric vaporizing units.

We also investigated the distribution, availability, and stocking patterns of antimosquito products in neighborhood stores in rural, suburban, and urban areas. Five small neighborhood stores were surveyed for the availability of mosquito protection products in rural and semiurban communities in Thailand (data omitted). The products stocked on the shelves depended on the size of the store. Even small corner stores, such as 1 in Soi Jumpa (of 5 such stores), stocked a wide range of aerosol and mosquito coil products. Midsize stores in rural areas such as in Mae Hong Son Province (data omitted) also stocked a wide variety of products.

We also made a survey of products stocked in 3 supermarkets in urban areas. We only report the data on product availability in 1 of the markets. In the Central Plaza Market in Bangkok, we surveyed only the aerosol products that dominated the supplies stocked. Additionally, we recorded the recommended uses of each product given on the label (Table 3). With the exception of 4 products, which were designated for ant, cockroach, and termite control, all were primarily labeled for mosquitoes. This trend was also noted in the other stores. In 90% of the product labels, mosquitoes were listed as the 1st group of target insects. Most of the products also listed other pests, including cockroaches, ants, flies, spiders, and other household invertebrate pests. In urban areas, the availability of mosquito protection products was determined in 2 of a large

Table 1. Aerosol formulations available in Thailand for personal protection from mosquitoes (1999).

Manufacturer or distributor	Trade name[1]	Active ingredients %
ARS Chemical Co., Ltd. (Bangkok, Thailand)	ARS Gold OB	Tetramethrin 0.05, dichlorvos 0.50
	ARS 3 Red OB	Tetramethrin 0.20, permethrin 0.10, dichlorvos 0.50
	ARS WB	D-allethrin 0.06, D-tetramethrin 0.06, permethrin 0.18
	ARS Mite OB	Cypermethrin 0.12, dichlorvos 0.50
	Household Insecticide	Deltamethrin 0.07, dichlorvos 0.50
Aswin Superman Co., Ltd. (Bangkok, Thailand)	Aswin Gold OB	Dichlorvos 0.50
	Aswin DPP OB	Dichlorvos 0.50, permethrin 0.10, D-allethrin 0.10
Bayer Thai Co., Ltd. (Bangkok, Thailand)	Baygon Blue WB	Cyfluthrin 0.025, transfluthrin 0.04
	Baygon Green 3 OB	Propoxur 0.50, cyfluthrin 0.025, dichlorvos 0.50
	Baygon Yellow 1 OB	Transfluthrin 0.03, dichlorvos 0.50
Cocksec Chemical Industry Co. (Bangkok, Thailand)	Kincho Blue WB	D-Tetramethrin 0.30, permethrin 0.04
	Kincho Green OB	Phthalthrin 0.05, fenitrothion 0.20, dichlorvos 0.50
	Kincho Orange WB	D-Tetramethrin 0.30, cyphenothrin 0.04
	Kincho Red WB	D-Tetramethrin 0.30, cyphenothrin 0.09
S. C. Johnson Co., Ltd. (Bangkok, Thailand)	Raid WB	Prallethrin 0.045, permethrin 0.10, pyrethrins 0.05
	Raid Plus WB	Prallethrin 0.06, permethrin 0.20
	Raid Maxx OB	Propoxur 1.00, tetramethrin 0.20, orthophenylphenol 0.15
Reckitt and Colman Co., Ltd. (Slough, Berkshire, United Kingdom)	Shieldtox Blue WB	*S*-Bioallethrin 0.10, permethrin 0.15
	Shieldtox Green OB	Tetramethrin 0.23, deltamethrin 0.10
	Shieldtox Odourless 1 WB	Bioallethrin 0.241, bioresmethrin 0.046
	Shieldtox Odourless 2 WB	Permethrin 0.279, tetramethrin 0.138
	Shieldtox Odourless 3 OB	Prallethrin 0.0729, D-phenothrin 0.1003
	Shieldtox Yellow OB	*S*-Bioallethrin 0.10, permethrin 0.20, dichlorvos 0.50

[1] OB, oil based; WB, water based.

Table 2. Coils and vaporizing products available in Thailand for personal protection against mosquitoes (1999).

Manufacturer or distributor	Trade name	Active ingredients %
	Mosquito coils	
ARS Chemical Co. Ltd.	ARS	D-Allethrin 0.20
Bayer Thai Co., Ltd.	Baygon	Transfluthrin 0.03
Cocksec Chemical Industry Co., Ltd.	Kincho	D-Allethrin 0.25
	Elephant	D-Allethrin 0.3
Family Products (Malaysia)	Raid Black Coil 2	NA[1]
Fumakilla/Technopia (Penang, Malaysia)	Elephant 1	D-Allethrin 0.30
	Elephant 2	Esbiothrin 0.15
Goose Limited	Product 3	Pynamine Forte 0.2
S. C. Johnson Co., Ltd.	Raid Smokeless Coil	Esbiothrin 0.10
	Raid	D-Allethrin 0.20
Reckitt and Colman Co., Ltd.	Shieldtox	Esbiothrin 0.10
Sahasamakee Yin Hua Co., Ltd.	Three Goats	D-Allethrin 0.20
	Three Goats (stick)	D-Allethrin 0.125
Swan Co., Ltd. (Thailand)	Swan 1	Esbiothrin (Allelthrin) 0.10
	Swan 2	D-Allethrin 0.20
	Vaporizing products[2]	
ARS Chemical Co., Ltd.	ARS Mat	D-Allethrin 40 mg/mat
	ARS Liquid	D-Allethrin 2.8
Bayer Thai Co., Ltd.	Baygon Mat 50	D-Allethrin 50 mg/mat
S. C. Johnson Co., Ltd.	Raid 45 (2 in 1)	Esbiothrin 3.0 liquid, D-Allethrin 40 mg/mat
Reckitt and Colman Co., Ltd.	Shieldtox Mat	Prallethrin 10 mg/mat

[1] NA, not available.

[2] Electric heating units are available separately for both liquid and solid formulations.

Table 3. Household insecticide formulations (aerosols) available in a large supermarket (Central Plaza) in Bangkok, Thailand, for personal protection against household insects (1999).

Manufacturer or distributor	Aerosol insecticides[1]	
	Formulations[2]	Allowable uses
ARS Chemical Co.	ARS Household Insecticide	Mosquitoes, others
	ARS 3 Household Insecticide	Mosquitoes, others
	ARS Mite Household Insecticide	Ants, termites
	ARS Mosquito Killer WB	Mosquitoes
Bayer Co.	Baygon Blue 1	Mosquitoes, others
	Baygon Foam Spray	Ants, termites
	Baygon Green 3	Mosquitoes, others
	Baygon Yellow 1	Mosquitoes, others
Clearview Co. (Thailand)	Lemonene Insecticide	Mosquitoes
Cocksec Chemical Industry	Kincho Green	Mosquitoes, others
S. C. Johnson	Raid	Mosquitoes
	Raid Plus	Mosquitoes
Johnson Wax (Bangkok, Thailand)	Raid Maxx	Cockroaches, others
Reckitt and Coleman Overseas Ltd.	Shieldtox Odorless 1	Mosquitoes, others
	Shieldtox Water-based	Mosquitoes, others
	Shieldtox Yellow 1	Mosquitoes, others
Sherwood Chemical (Bangkok, Thailand)	Shelldrite 1	Ants, cockroaches, termites

[1] For composition, see Tables 1 and 2.
[2] Mosquito coils and vaporizers and repellents also stocked, but not listed here.

chain of supermarkets (Tops Super Market), 1 in Nonthaburi Province (central Thailand), and 1 in Chiangmai Province in northern Thailand (data omitted). As in other large stores and markets, aerosol products dominated. The range of products stocked in each supermarket was essentially the same, although the number of aerosol products in the market in Chiangmai was greater. Urban supermarkets apparently stock more aerosols than coils because the demand for coils in urban areas is lower than in rural or low-income communities.

Thailand offers a wide variety of products and formulations designed to reduce the impact of host-seeking mosquitoes. Although we did not assess the prevalence of other household pests, in discussion with the residents, it became obvious that they rated mosquitoes very high in terms of annoyance and their out of pocket expenditures for purchase of household insecticides.

No published data are available on the use of mosquito protection chemicals and devices in Thailand or most of Southeast Asia. As to the use of commercial household insecticide products, in a study in neighboring Malaysia, Yap and Foo (1984) reported extensive use of aerosol products and mosquito coils. Oil-based liquid sprays and mosquito nets were used by a lower proportion of the households. In a 2nd study, Yap et al. (2000) reported that 70% of the households used some kind of control measure, but the use of household insecticides was the most preferred. The use of aerosol insecticides and mosquito coils was prominent. Vaporizing mats were used only by few of the households, which is also the case in Thailand. In Thailand, from the quantity and kinds of household insecticide products stocked in stores and supermarkets, we conclude that aerosols and mosquito coils are the 2 groups of products used in larger volumes than other products, with the coils primarily by the low-income sector.

Efficacy of mosquito protectants

The effectiveness and duration of protection afforded by household insecticides is difficult to address. Most of the efficacy data have been gathered by the manufacturers and are not published. Some efficacy studies have been conducted in neighboring Malaysia. Yap and Chung (1987) conducted laboratory studies on the knockdown effects and mortality using mosquito coils containing D-allethrin and D-transallethrin. They showed that *Cx. quinquefasciatus* is less prone to knockdown effects than some other mosquito species, but had 62% mortality after 24 h. In a study inside houses in Malaysia, Yap (1988) evaluated aerosols, mosquito coils, electric vaporizing mats, and oil-based liquids and determined the reduction in mosquito landing and biting rates over a 4-h period to be 53, 54, 70, and 18%, respectively.

We evaluated 3 representative commercial mosquito coils. The 3 mosquito coils showed similar trends in the reduction of landing–biting mosquitoes. Baygon coils (0.3% transfluthrin) showed a reduction of 77–85%, Swan 2 (0.2% D-allethrin), 72–96%, and Elephant 2 (0.15% esbiothrin), 78–93% (Table 4). In these studies, 6 species of mosquitoes were attracted to human hosts. The composition is given only for the control group, because the numbers of the less dominant species attacking humans under the protection of the coils was very low, ranging from 0 to 4 mosquitoes dur-

Table 4. Reduction in landing–biting rates of mosquitoes outdoors in the presence of 3 commercial mosquito coils.

Date (1999)	Temperature (°C)	Total mosquitoes[1] captured (percent reduction) in presence of coils			
		Type of antimosquito coil			
		None (Control)	Baygon	Swan 2	Elephant 2
September 12	24.3	80 (—)	18 (77)	12 (85)	11 (86)
October 12	24.1	51 (—)	8 (84)	14 (72)	11 (78)
November 12	25.6	122 (—)	18 (85)	5 (96)	8 (93)

[1] In 12 collections (10 min each) from 1800 to 2100 h.

ing the entire test period. In the control group, *Cx. quinquefasciatus* constituted 39–80% of the attacking mosquitoes. The other species attacking were *Culex gelidus* Theobald (11–30%), *Cx. tritaeniorhynchus* Giles (4–8%), *Armigeres subalbatus* (Coquillett) (0–12%), and *Mansonia dives* (Scheiner) (17% in December but 2.5–4.0% in the other 2 tests). Numbers of *Mansonia uniformis* (Theobald) and *Ae. aegypti* were insignificant.

Field studies on the efficacy of mosquito coils containing D-allethrin and D-transallethrin were carried out in living rooms in squatter housing projects in Malaysia (Yap et al. 1990). In this study *Cx. quinquefasciatus* constituted about 85% of the landing–biting mosquitoes. Four mosquito coil formulations tested indoors yielded 29–75% reduction in the landing–biting rate of mosquitoes. In another study using mosquito coils containing either transfluthrin or D-allethrin in houses in a squatter community, all formulations provided good protection (>90%) from biting mosquitoes over a 4-h period (Yap et al. 1996). On the basis of our studies and those in Malaysia, mosquito coils seem to be able to provide good protection from mosquito bites and annoyance if coils are placed relatively close to individuals to be protected.

Published data on the efficacy of aerosols, liquid sprays and vaporizing devices in field situations in Southeast Asia are scanty. However, analysis of our data shows that large quantities of aerosols and mosquito coils are used in Thailand, followed by liquid sprays and vaporizers. Mosquito repellents are used sparingly.

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REFERENCES CITED

Morris CD, Clanton KB. 1988. Quantification of a nuisance mosquito problem in Florida. *J Am Mosq Control Assoc* 4:377–379.

Morris CD, Clanton KB. 1989. Significant associations between mosquito control service requests and mosquito populations. *J Am Mosq Control Assoc* 5:36–41.

Mulla MS, Rodcharoen J, Ngamsuk W, Tawatsin A, Pan-Urai P, Thavara U. 1997. Field trials with *Bacillus sphaericus* formulations against polluted water mosquitoes in a suburban area of Bangkok, Thailand. *J Am Mosq Control Assoc* 13:297–304.

Mulla MS, Su T-Y, Thavara U, Tawatsin A, Ngamsuk W, Pan-Urai P. 1999. Efficacy of new formulations of the microbial larvicide *Bacillus sphaericus* against polluted water mosquitoes in Thailand. *J Vector Ecol* 24:99–110.

Yap HH. 1988. Household pests and household insecticide use in Malaysia. *MACA Newsl* 1:11–12.

Yap HH, Chung KK. 1987. Laboratory bioassays of mosquito coil formulations against mosquitoes of public health importance in Malaysia. *Trop Biomed* 4:13–18.

Yap HH, Foo AES. 1984. Household pests and household insecticide usage on Penang Island, Malaysia—a questionnaire survey. *Bull Public Health Soc* 16:2–8.

Yap HH, Lee CY, Chong NL, Yahaya AM, Baba R, Awang AH. 1996. Performance of mosquito coils containing transfluthrin against *Culex quinquefasciatus* (Say) in an urban squatter environment. *Trop Biomed* 13:101–103.

Yap, HH, Lee YW, Ong CH, Ridzuan I, Quah ES, Chong NL. The abundance and control of household pests in Penang, Malaysia—questionnaire and trapping survey. *J Biosci* (in press).

Yap HH, Tan HT, Yahaya AM, Baba R, Loh PY, Chong NL. 1990. Field efficacy of mosquito coil formulations containing D-allethrin and D-transallethrin against indoor mosquitoes especially *Culex quinquefasciatus* Say. *Southeast Asian J Trop Med Public Health* 21:558–563.